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Artificial Insemination

Appendix

Note : Parts I to V of this Report constitute the Report of Proceedings under the Diseases of Animals Act, 1950

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REVIEWS AND ABSTRACTS

In this section of the N.A.A.S. Quarterly Review, it is intended to survey current research and experiment in agriculture, horticulture and the allied sciences applicable to the work of the National Agricultural Advisory Service. It will not be possible, of course, to cover more than a small part of this wide field in each issue.

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Hormones in Fertility

JOHN HAMMOND

Formerly Hon. Director, A.R.C. Unit of Animal Reproduction, School of Agriculture, Cambridge

ABOUT THIRTY YEARS AGO it was shown that if, in a rabbit which was shedding 5 eggs from each ovary, one ovary was removed, then the remaining ovary shed not 5 but 10 eggs. From this it was concluded that the number of eggs shed depended on the level of a certain substance in the blood, and not on the ovary itself. Later it was found that this special substance came from the anterior pituitary gland at the base of the brain. As we now know them, the main hormones affecting fertility are as shown in Plate II.

There are two main anterior pituitary hormones:

(*a*) *Follicle stimulating hormone* (FSH), a cheap substitute for which is to be found in the blood serum of mares pregnant between 45 to 90 days (PMS). This, when injected intramuscularly or subcutaneously, so as to have a slow continuous action, causes the follicles to ripen in about 4 days. As a result of the ripening of the follicles, oestrogens are produced and circulate in the blood giving rise to the symptoms of heat.

(*b*) *Luteinizing hormone* (LH), a cheap substitute for which is found in pregnant woman's urine (PU). This, when injected intravenously, so as to have quick action, causes the follicles to rupture, liberate the eggs and form corpora lutea. The corpora lutea produce progesterone which circulates in the blood stream and causes the uterus to produce substances to nourish the developing egg. Later in pregnancy both progesterone and oestrogens are produced by the placenta as well.

The proportions of FSH to LH in the anterior pituitaries of the different species of farm animals vary considerably and are probably the cause for the differences in the reproductive processes (shown in Plate III). Under conditions of lowered anterior pituitary activity the scarcest hormone is usually the cause of the lowered fertility involved. For example, in a cold, dry spring the mare has difficulty in shedding the egg from the follicles because of the low LH production from the anterior pituitary, and so has long heat periods during which service is not fertile because the egg is not shed. Intravenous injection of PU immediately after service causes the egg to be shed within 24 hours and raises fertility. On the other hand, during winter the young cow, because of its high LH in proportion to FSH, ovulates very quickly, so that the duration of heat is very short, or heat may not occur at all ('still heat'), for the LH may rupture the ripening egg before it has time to produce enough oestrogen to cause heat to appear.

Recently attempts have been made to utilize this knowledge about reproductive hormones not only to be able to deal with cases of sterility, but also to use them for increasing the natural fertility of the animal in order to lower costs of production.

Increased Fertility in Cattle and Sheep

In our meat-producing animals, as early maturity is increased and the age at slaughter reduced, high fertility becomes more important in order to reduce the overhead charges on the cost of the dam's keep. This is particularly evident in the cost of the calf of a pure beef breed at birth. Attempts have therefore been made to obtain twins in beef cattle by hormone injection. The number of eggs shed depends, among other things, on the dose of PMS injected. With high doses, up to 50 eggs can be shed at one heat period. However, it has been found that, with both cattle and sheep, the number of embryos in excess of the maximum number produced by the species die off, mainly in an early stage of development. It seems probable that there is an undiscovered nutritional substance in the uterus, the amount of which limits the number of embryos which will develop. Until this is discovered we cannot hope for litters of cattle or sheep.

It has been shown, however, that about 2,000 i.u. of PMS injected subcutaneously in cows some 4 days before the expected heat period will, on average, produce twins, although some cows will produce singles and some triplets. It is not known yet whether this variation is caused by differences in the weight of the cow or by other factors. The difficulty with beef cows suckling calves, however, is to know when to expect the next heat period, since signs of heat are difficult to detect. Experiments by Rowson and Lamming at Cambridge and recently by Lamming at the Nottingham School of Agriculture have shown that beef cattle will respond to squeezing out the corpus luteum and injecting 2,000 i.u. PMS at the same time.

Various objections have been raised against the production of twins in cattle. Heifer calves co-twin to a bull are usually sterile (freemartins), but they are equally good for beef purposes. Twin calves are usually weaker than singles, but if 'steaming up' is practised the twin calves will be strong at birth, as is the case with twins in sheep. Although hormone injections to obtain twins in beef cattle may be useful as a temporary expedient, the breeding of 'twinning strains' of beef cattle should be the ultimate solution; the same thing also applies to sheep.

There are two ways in which sheep fertility can be increased. Firstly, by raising the percentage of twins during the normal breeding season, and secondly, by getting the ewe to breed all the year round and so produce two crops in the year, or at any rate three crops in two years.

Under lowland conditions where fat lamb production is the aim, the lambing percentage plays a large part in the profitableness of the flock. For this reason certain breeds and crosses have not as wide a

popularity as their wool and mutton qualities might suggest. While 'flushing' (raising the plane of nutrition for three weeks before and during the time the ram is put in) will increase the lambing percentage in all breeds, this is not always possible because of feed conditions at the time. Early small-scale experiments with a research flock showed that subcutaneous injections of 500 i.u. PMS given on the 12th day of the cycle, or 4 days before the expected heat, raised the lambing percentage to 167 per cent, as compared with 147 per cent for the controls. Field trials in New Zealand, Iceland and in this country have also been successful, and this method should prove useful in those breeds and areas where the lambing percentage is normally low. Gordon, working from Cambridge on flocks of different breeds and in different parts of the country this year has obtained good results. However, he found that if high doses are given, quadruplets and quintuplets occur in some breeds, so that a dose of about 500 i.u. seems to be about right for most breeds. The method adopted is to run a sterile (vasectomized) ram with the flock and as he marks the ewes, take them out and inject them 12 days afterwards, at the same time turning them in with the fertile ram.

Two Crops of Lambs a Year

It would be a great advantage to be able to obtain two crops of lambs a year in fat lamb producing flocks. Not only would this reduce overhead costs on the keep of the ewe, but also it would prevent ewes, whose lambs are weaned at an early age, from getting too fat, for this lowers fertility at the next breeding season, and also renders them more liable to pregnancy toxaemia in the next pregnancy.

Earlier experiments showed that the cause for the breeding and non-breeding seasons in sheep is the variation in daylight hours. Long nights and short days act on the nerves in the region of the head (like morse code signals in slow motion) to stimulate the anterior pituitary to increase its FSH hormone production; short nights and long days depress its activity.

The injection of 800 i.u. of PMS in the non-breeding season causes the follicles to ripen and sufficient LH is produced by the ewe's own pituitary to cause these to rupture so that the eggs are shed. However, as shown in Plate III, the ewe is like the cow with an excess of LH in the pituitary, and often the follicles are caused to ovulate before sufficient œstrogens are built up to cause heat. It was found therefore that the eggs were almost invariably shed after injections of PMS during the non-breeding season, but only a few lambs were produced. Those ewes which did come on heat had an old corpus luteum in the ovary, since there may be occasional spontaneous ovulations during the non-breeding season. Consequently injections of progesterone (the hormone produced by the corpus luteum) were then given for a few days before PMS was injected, with good results in many cases. Gordon, who has been making these experiments

on many farms, finds that better results have been obtained in sheep which are not suckling, for during the first 2 or 3 months there seems to be a lactation anoestrus in addition to a non-breeding season effect. One thing seems fairly certain; ewe lambs when they are about a year old can be injected with progesterone and PMS in April-May and produce a crop of lambs in September-October to be finished off on sugar beet tops (Plate I). They will take the ram again in October-November to lamb down the following year on grass in March-April. Starting with ewes already suckling lambs, the results so far have been variable, but it is hoped that further experiments may make the method more reliable.

Transplantation of Fertilized Ova

To exploit these hormones for the benefit of animal breeding, various exploratory experiments have been in progress, particularly with small animals like the rabbit. Genetic progress is much faster in small animals because the interval between generations is much shorter. In rabbits it was found that the anterior pituitary hormones injected in immature animals would cause shedding of the eggs, and that these could be fertilized, but the embryos perished because of the lack of the unknown substance necessary for development in the young animal. However, if these fertilized eggs were transferred to an adult doe in the same reproductive state, they would develop and produce normal young. Experiments were then made with calves, and it was found that by giving injections of PMS, a calf could be made to produce eggs before it was a month old and these eggs could be fertilized. Transplantation of such eggs into adult cows is awaiting a simple method of egg transplanting in cattle (see below). If this could be found it would be possible to obtain a generation a year in cattle, and for a cow to be a grandmother by the time she became a mother by natural methods.

By using these anterior pituitary hormones to increase the number of eggs shed in conjunction with the method of fertilized ova transplantation, one should be able to do for the cow what artificial insemination has done for the bull. A heifer begins life with about 75,000 ova in her ovaries, and improved techniques should make it possible to obtain many of these for transplantation into cows of less genetic worth. This has been done in rabbits; a doe was injected with FSH and the 50 fertilized eggs were transplanted 10 at a time into 5 incubating does, which averaged 8 young at birth. It is not necessary to kill the mother to obtain the eggs, for they can be washed out of her tubes. Again, if a simple method of ova transfer could be devised for the cow, it should be possible for Channel Island cows, not wanted to breed dairy replacements, to produce pure Aberdeen-Angus calves for beef purposes. Egg transplantation has been done successfully in the cow, but, as in rabbits and sheep, it requires an operation

to put the egg in. This, of course, is not practical on the farm, and some simple method has yet to be devised. Trials were made with the inseminator used for artificial insemination and the eggs were put in at 4-5 days after heat when they would normally be coming down from the tube to the uterus. However, difficulties were encountered, due to hormone action. When the cow is on heat the uterus is under the influence of oestrogens from the follicle and there is a film of mucous which neutralizes any bacteria which may enter with the semen. At 4-5 days after heat the uterus comes under the influence of progesterone from the corpus luteum so that it produces uterine milk to nourish the developing embryo. This uterine milk forms an excellent media for any bacteria entering from the cervix to grow in, and so infection of the uterus is caused. Further research is required and perhaps some critical time or condition may be found when it will be possible for the egg to live until the uterine milk begins to be formed.

Other Possibilities

Fertilized rabbit eggs can be kept alive outside the body for 4 days by keeping them in blood serum at temperatures above those used in artificial insemination. They have been flown across the Atlantic and have produced young when incubated in does here. The rabbit egg, however, keeps better outside the body than the eggs of other species—perhaps because it has a thick albumen layer put over it in the tubes. One could transport thousands of fertilized eggs in a small thermos flask at small cost. This leads to the possibility of exporting our pedigree stock by the same means, thus reducing the present high transport costs.

The fertilized eggs of our farm animals have no albumen layer, and attempts have recently been made with fertilized sheep ova to see whether they would live in the rabbit, at any rate for a time sufficient to send them by air to, say, South Africa. Quite recently at the A.R.C. Unit of Reproductive Physiology and Biochemistry at Cambridge, it has been found that if fertilized sheep ova are put into the tubes of rabbits in the 2-cell stage, they will acquire an albumen layer like the rabbit's egg and will continue to develop—at any rate to the 8-day stage. If they are then taken out and put back into a ewe they will continue their development. Whether cattle eggs will develop in the rabbit and, if so, how far they will go in development is not yet known, but this does seem to open up possibilities for the future.

Detailed references may be obtained from 'Hormones in relation to fertility in farm animals', by John Hammond, *Brit. Med. Bull.* (1955), **11**, 165.

The Interpretation of Field Trial Results

E. R. BULLEN

National Agricultural Advisory Service, Eastern Province

EVERY ADVISER is at one time or another called upon to interpret the results of field experimental work. It is hoped that the following notes, which explain the methods normally used for presenting results, will make this task easier. Statistics, being a branch of mathematics, can never, of course, be made wholly intelligible except in a mathematical way, but the following rather 'rough and ready' guide should help to clarify certain difficulties and assist advisory officers to decide whether results are real or spurious.

When interpreting an experimental result, four questions should be asked:

How do I know that this trial is reliable?

What do the results mean?

Does the conclusion apply to my district?

Is the result practical and economic?

How do I Know that this Trial is Reliable?

This first question can be sub-divided into three further questions:

(*a*) *Is the average yield reasonable?* Trial results should include a statement of the crop yield in customary farming terms. Normally the results of each treatment are given in this way, but occasionally they are shown as percentages of the general mean, or sometimes (e.g., in a series of variety trials where different varieties are grown at each centre) as percentages of the control. The results from trials with very low yields should be regarded with suspicion; those from centres with very high yields may not be typical of normal farming conditions.

(*b*) *Is the trial accurate?* No field experiment can be completely accurate, but the degree of inaccuracy can be indicated by the *Standard Error per Plot.* This is a method of expressing the variation in plot yields due to causes other than the experimental treatments. The figure

is calculated by statistical methods and, for comparison between trials, it is normally expressed as a percentage of the mean yield, e.g.,

S.E. per plot = 1.56 cwt. or 5.8 per cent.

In agricultural field trials, a low S.E., indicating that the trial has been accurately conducted, should be the experimenter's aim. In cereal trials such as the N.I.A.B. variety trials, the S.E. per plot is usually below 8 per cent; trials on roots are less accurate and the S.E. per plot is usually between 8 per cent and 12 per cent. A field trial with an S.E. per plot exceeding 15 per cent may be unreliable; one where it exceeds 25 per cent is almost useless.

High S.E.s per plot are not necessarily due to inaccurate field work—often they reflect the selection of a bad site or the use of an unsuitable design for the trial.

(*c*) *Does the result confirm accepted views?* Trials with which advisory officers are concerned are seldom those of fundamental research work. More often they concern the local application of some general principle which has already been established. It is therefore imprudent to trust the 'freak' result which occurs occasionally. There have, for example, been N.A.A.S. potato trials in the Eastern Province where potash has appeared to depress the yield of maincrop potatoes, an effect actually due to the potash delaying maturity and the crop then being killed by a very early and severe blight attack.

In addition to checking results against generally accepted principles, it is important to be able to make a comparison with other trials of any series. Although responses over a series of trials will vary owing to soil, weather and other factors, there should be some consistency in the majority of the trials. To provide a reasonable basis, therefore, the experiment should be one that has been repeated at a number of centres over several seasons. A single experiment, even if repeated for a second year, may not give reliable results.

What do the Results Mean?

There are many ways of tabulating the results of trials; the following examples illustrate some of those most commonly met:

LATIN SQUARE OR RANDOMIZED BLOCK EXPERIMENTS

The results of such experiments are usually set out as in Table 1 overleaf.

Table 1
Yield of Peas as Threshed
(cwt. per acre)

Mean	No Fertilizer	Fertilizer Broadcast		Placed Fertilizer $2\frac{1}{2}$ cwt./acre	S.E. per Treatment Mean	Significant Difference
		Low Rate $2\frac{1}{2}$ cwt./acre	High Rate 5 cwt./acre			
(1)	(2)	(3)	(4)	(5)	(6)	(7)
26.9	24.1	25.9	26.5	31.2	0.64	1.93

S.E. per plot=1.56 cwt. or 5.8 per cent

Two S.E.s are quoted in this table; the S.E. per plot of 5.8 per cent shows that the trial was reasonably accurate. The figures for the S.E. per treatment mean* of 0.64 is used by the statistician to calculate a figure for the *Significant Difference* (Column 7) which can be used to show whether the differences between the treatment means (columns 2-5) are significant. In this example the yield under column 5 is clearly significantly greater than the yields under columns 2, 3 and 4.

It is quite possible for an experiment to produce a 'result' due to chance; for example, the plots of one treatment may happen to be sited on highly fertile patches in the field. Significance is an arbitrary mathematical method of deciding whether any result is a genuine response, or just one of these chance occurrences. Any significant response is usually large enough to be of practical importance, but non-significant responses are not necessarily non-existent. Tests of significance are based on the theory of probability; they can never guarantee that a response is genuine, but merely enable one to quote the probability that it is so. Conventionally, a 20:1 probability (sometimes quoted in the form P=0.05) is used in deciding whether field trial results are significant. Genuine effects can appear non-significant owing to an inaccurately executed trial or a layout which is badly chosen, and tests of significance need to be interpreted with judgment.

Significant Differences are sometimes quoted, as in Table 1, but where they are not given, they can be calculated. The difference between two treatment means is significant if it is roughly three times the standard error of a treatment mean. In the example given:

$$3 \times 0.64 = 1.92$$

This approximate method of testing significance is not sufficiently accurate for critical work, and a more detailed calculation (which is not reviewed here) gives the accurate value 1.93 used in Table 1.

---

*The S.E. per treatment mean is obtained from the S.E. per plot by dividing by the square root of the number of plots contributing to the mean. In this example there were six replicates; therefore:

$$\frac{1.56}{\sqrt{6}} = \frac{1.56}{2.45} = 0.64$$

An alternative method of presenting the results of this experiment would be to tabulate the responses to treatments, instead of the treatment means.

Table 2
Yield Responses of Peas as Threshed
(*cwt. per acre*)

Yield without Fertilizer	Yield Increase from Broadcasting		Yield Increase from Placement	S.E.	Significant Difference
	Low Rate	High Rate			
24.1	1.8	2.4*	7.1*	0.93	1.93

Here the results are presented as *differences* of treatment means. Accordingly the S.E. is not the same as in the previous example, since it has been calculated by a different method. However it gives the same result in a test for significance. For approximate calculations, the difference between two means is significant if it exceeds twice the S.E. of the difference (in this example $2 \times 0.93 = 1.86$).

Placing an asterisk against a response (as 7.1*) denotes a significant response at the 20:1 level. Double asterisks are similarly used to indicate a response which is significant by the more rigorous 100:1 ($P=0.01$) test, but this is rarely used for the results of field trials.

FACTORIAL EXPERIMENTS

Factorial experiments include more than one kind of treatment. For example, they may study the effect of manuring on several varieties of cereals, or compare the effects of different fertilizers on a crop. Being more complicated they are more liable to cause confusion of interpretation. It is first necessary to distinguish between the responses to each of the treatments individually ('main effects') and their influence on each other ('interactions').

A factorial experiment on the manuring of potatoes gave the following results:

Yield of Potatoes
(*tons per acre*)

	No Dung	Dung	Mean
No potash	2.8	9.0	5.9
Potash	7.8	11.6	9.7
Mean	5.3	10.3	7.8

The crop obviously responded well to dung and potash. However, the table needs closer scrutiny if all the information is to be drawn from it.

The mean figures tabulated give the 'main effects' of dung and potash: these correspond to the treatment responses in a non-factorial trial, the other factor (or factors) being averaged out. These effects are:

Main effect of Potash = 9.7 − 5.9 = 3.8 tons per acre
Main effect of Dung = 10.3 − 5.3 = 5.0 tons per acre

Closer examination of the table reveals that the potash response, as would be expected, is greater without dung than where dung has been applied. This means there is an interaction between dung and potash. The interaction in this experiment can be calculated by comparing the mean of the yields obtained in the presence and in the absence of both potash and dung $\left(\frac{11.6 + 2.8}{2}\right)$, with the mean of the yields obtained from potash alone and dung alone $\left(\frac{9.0 + 7.8}{2}\right)$. Thus:

$$\text{Interaction potash-dung} = \frac{11.6+2.8}{2} - \frac{9.0+7.8}{2}$$

$$= \frac{14.4}{2} - \frac{16.8}{2}$$

$$= -1.2 \text{ tons per acre}$$

Interactions may be positive or negative; in a negative interaction the effect of one factor is reduced by the other, in a positive interaction the effect of one factor enhances the other. It is possible to apply tests of significance to interactions, but the results are not always of practical value.

EXPERIMENTS AT SEVERAL LEVELS

Agricultural experiments are often carried out not merely with a number of factors, but with each factor at several levels. One of the most common layouts used is the '3 × 3 × 3' which investigates three factors, each at three levels. In the following example the treatments given to a celery crop were:

Nitrogen	NIL
	1½ cwt. per acre sulphate of ammonia
	3 cwt. per acre sulphate of ammonia
Phosphate	NIL
	7 cwt. per acre superphosphate
	14 cwt. per acre superphosphate
Potash	NIL
	3 cwt. per acre muriate of potash
	6 cwt. per acre muriate of potash

Results were as follows:

Table 3

Total Yield of Celery
(*tons per acre*)

		Phosphate *cwt. superphosphate per acre*			Potash *cwt. muriate of potash per acre*			Mean ($\pm$0.935)
		0	7	14	0	3	6	
		($\pm$1.619)						
NITROGEN (cwt. sulphate of ammonia per acre)	0	28.49	25.55	27.12	24.67	27.24	29.29	27.06
	$1\frac{1}{2}$	20.83	25.02	25.55	18.18	26.20	27.02	23.80
	3	16.35	21.77	24.12	17.04	20.57	24.64	20.75
PHOSPHATE (cwt. superphosphate per acre)	0				17.63	24.34	23.71	21.89
	7				20.45	22.77	29.13	24.12
	14				21.80	26.90	28.09	25.60
Mean ($\pm$0.935)		21.89	24.12	25.60	19.96	24.67	26.97	23.87

S.E. per plot = 2.805 tons per acre or 11.8 per cent

This type of table needs systematic examination if full value of the trial results is to be obtained.

Examine the main effects first: these are obtained from the marginal means of Table 3. It is usual to examine the effect produced by the higher level of each treatment.

Treatment	Mean Yield	Main Effect
N 0	27.06	20.75 − 27.06 = −6.31
N 3	20.75	
P 0	21.89	25.60 − 21.89 = +3.71
P 14	25.60	
K 0	19.96	26.97 − 19.96 = +7.01
K 6	26.97	

S.E. of treatment means $\pm$0.935 Significant difference = $\pm$2.84

There are clear responses to potash and phosphate and a well-marked reduction in yield from nitrogen. All main effects are significant since they exceed 2.84.

Next, tabulate the interactions. These are:

$$
\begin{aligned}
NP &= \frac{24.12 + 28.49}{2} - \frac{27.12 + 16.35}{2} \\
&= 4.57 \\
NK &= \frac{24.64 + 24.67}{2} - \frac{29.29 + 17.04}{2} \\
&= 1.49 \\
PK &= \frac{28.09 + 17.63}{2} - \frac{23.71 + 21.80}{2} \\
&= 0.10
\end{aligned}
$$

The PK interaction is obviously negligible, and the NP interaction the most important. Scrutiny of the part of the table dealing with N and P confirms that the yield depression due to N is reduced by the presence of P.

It will be noted that there are two S.E.s in the tabulated results of this factorial. The S.E. 0.935 relates only to comparisons between marginal means, and 1.619 must be used only for comparisons made in the body of the table. Since the number of plots contributing to a mean affects its S.E., the S.E. for marginal means (each derived from 9 plots) is less than the S.E. for the main table (each figure of which is the mean of 3 plots).

LINEAR AND CURVATURE COMPONENTS

There is a further examination possible to both main effects and interactions—their subdivision into linear and curvature components. A linear response is one where the response to the second increment of the treatment is approximately equal to the response to the first increment. (The main effect of nitrogen on celery in Table 3 is approximately linear.) Curvature is a measure of the degree to which a response diverges from the linear. In practice, a linear response is obvious; the curvature component is rarely significant unless the trial is exceptionally precise.

The practical value of this more detailed examination of these main effects is that one can obtain some idea of the optimum level at which to use fertilizers. In the celery trial quoted, the yield increase given by 3 cwt. muriate of potash is over $4\frac{1}{2}$ tons of celery (24.67—19.96), but a further 3 cwt. has given only half this response. Even if this use of 6 cwt. were economic, it is unlikely to pay if much beyond that level were applied.

In some trials, more than two S.E.s may be required in the calculations. If so, care is required to use the correct one in any test of significance.

Confusion may arise where a series of tables is presented from the same trial. Thus the results of a sugar beet trial may be expressed in

terms of root yield, top yield, yield of sugar, sugar percentage or noxious nitrogen percentage. It is usually most convenient to consider in detail the most applicable table—usually that most closely corresponding to the customary basis of selling the crop. In sugar beet this would normally be yield of sugar; with potatoes, yield of ware. The other tables can then have less detailed scrutiny.

Does the Conclusion Apply to my District?

In presenting the results of a series of trials, the experimenter should give the reader a good idea of the farming conditions under which his result was obtained. For example, information for the pea trial quoted in Tables 1 and 2 reads as follows:

Site . . .	Hunstanton, Norfolk
Date sown . .	15th Match, 1952
Variety . . .	Harrison's Glory
Soil . . .	Sandy loam
*p*H . . .	7.8
Available P . .	4.5 p.p.m. (Medium high)
Available K . .	14 p.p.m. (Very low)
Fertilizer used .	Granular compound (10 per cent P_2O_5, 20 per cent K_2O)

It is probable that the response obtained was largely due to potash, and that possibly on similar light, potash-deficient soils, a corresponding result might be expected. As the results in Table 2 and 3 were confirmed at five of the seven similar trials carried out in 1952 in this series on a range of soil types, it is reasonable to conclude that this result is of fairly wide application, particularly as a number of trials in previous years had given concordant results on mineral soils.

The two trials which did not show these marked responses to placement were the only two on fen soils. While there may be an explanation for this in the high nutrient status of the sites chosen, one must conclude that however valuable placement may be on the 'upland' soils, its value was non-proven in the fens on the results of that year's work.

Special care is needed in accepting results from overseas, where conditions may be completely different.

Is the Result Practical and Economic?

Experiments are conducted solely to provide information for the use of farmers, and an experiment is not really complete until the results have been made available in an easily understandable way. Naturally, some of the methods of tabulating results shown here are not those which one would use in conveying results to farmers in a 'popular' way.

Experimental findings are unlikely to be accepted by farmers unless the results are both capable of practical application and are likely to

prove remunerative. It is tempting to focus attention on the economic side of experimental work by converting results directly into cash. While this may have every justification in straightforward trials, such a course is often impossible. In trials such as experiments on straw disposal, for example, the process involves the preparation of the probable balance sheet for the farm under a number of alternative systems!

Farmers can derive very great benefits from the conclusions drawn from experimental work, and it is obviously desirable that these results should be made freely available once their validity has been proved. One word of warning, however—temper zeal with caution; for the confidence of the farming community can easily be undermined if premature publicity is given to trial results before their reliability and applicability have been thoroughly examined.

An article which should be read in conjunction with the above, entitled 'The Place of Statistics in Field Experiments' was published in No. 15 of this Review, Spring 1952. The co-authors were D. A. Boyd and G. V. Dyke, both of the Rothamsted Experimental Station.

Reviews and Abstracts

The Foliar Application of Nutrients for the Treatment of Deficiencies in Crops

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DEFICIENCIES FOUND DURING advisory work on crops in the Eastern Province are nitrogen, phosphorus, potassium, magnesium, iron, manganese, copper and boron. In Norfolk, West Suffolk and Bedfordshire, particularly after a wet winter, nitrogen and magnesium deficiencies occur very frequently on light sandy soils which are low in organic matter. Potassium deficiency is also common in these soils and in the light chalky soils of Cambridgeshire and Essex. Iron deficiency is fairly widespread in fruit-growing areas on chalky soils of the Province; on many peaty soils where the *p*H is over 6.0, deficiency of manganese is common. Deficiencies of the other elements are less widespread; phosphorus deficiency is found occasionally on the heavy soils of Essex and Suffolk; and in recent years copper deficiency has been the cause of serious failures of cereals growing on some of the peaty soils of Huntingdonshire, Cambridgeshire, the Isle of Ely and Norfolk, and also on some of the very light reclaimed heathland soils of Norfolk and East Suffolk. Instances of boron deficiency are found in most seasons on light soils where the *p*H is over 6.5 or where over-liming has taken place, and during a very dry summer it is widespread in sugar beet crops on these soils.

Crops vary in their susceptibility to deficiencies. The following table gives the crops that are susceptible to deficiencies commonly found in the Eastern Province:

Table 1

Deficiency	Susceptible Crops
Nitrogen	Cereals, brassica crops, sugar beet, cocksfoot.
Phosphorus	Brassica crops, cereals.
Potassium	Clover, lucerne, cocksfoot, potato, beans, barley, gooseberry, currants, apple.
Magnesium	Oats, barley, sugar beet, potato, kale, cabbage, carrot, apple, gooseberry, tomato.
Iron	Apple, pear, plum, raspberry, currants, strawberry.
Manganese	Oats, wheat, barley, mustard, sugar beet, potato, brassica crops, peas, dwarf and runner beans, onion, carrot, celery, cocksfoot, apple, plum, cherry, raspberry.
Copper	Wheat, barley, oats.
Boron	Sugar beet, brassica crops, celery.

Treatment of Deficiencies

Plants are able to absorb, and use rapidly, nutrients applied to their foliage, and the foliar method of applying fertilizers to the leaves of crops can be used for the treatment of all of the deficiencies, with the exception of iron. However, only relatively small amounts of nutrients can be applied to the foliage in one application, otherwise severe scorching and defoliation of plants may occur. Because of this limitation, it is not possible to supply the major element requirements of crops except by repeated foliar applications, carried out over a long period of the growing season. If a foliar treatment is to be successful there must be sufficient foliage to retain the applied nutrients, and crops cannot develop to a stage of growth when foliar treatment would be effective, unless they receive an adequate supply of nutrients from the soil at a very early stage of growth. The foliar method, therefore, cannot take the place of the traditional method of applying fertilizers to the soil. Nevertheless, it is very useful as a first-aid measure, to obtain a rapid response when major element deficiencies appear in established crops, and where a top dressing of fertilizer would act too slowly in correcting a deficiency, due, for example, to lack of moisture in the soil in a dry season. The stimulus to root growth following a foliar treatment can make it possible for a crop to use more readily nutrients in, or applied to, the soil.

The foliar method is also very useful in the control of trace element deficiencies which cannot be corrected efficiently by soil applications of fertilizers. For example, manganese applied to a soil which gives rise to manganese deficiency in crops may become quickly unavailable to crops. The deficiency can be overcome successfully by a foliar application of a small amount of manganese sulphate. In general, the soil application method is used for the prevention of deficiencies of nitrogen, phosphorus, potassium, magnesium and boron, and the foliar method for the most efficient control of manganese and copper deficiencies. Both soil and foliar methods may be required at first in the treatment of magnesium deficiency.

Response to foliar treatment can usually be observed in four days; full benefit occurs about two weeks after application. It must be emphasized, however, that indiscriminate foliar application of trace elements can be dangerous and can cause reduction in yields where crops are already receiving sufficient nutrients from the soil. Correct diagnosis of deficiencies is essential before foliar treatment can be recommended on a farm scale.

Methods of Foliar Application

Nutrients can be applied to plant foliage in dusts or sprays. Finely-ground fertilizer is required for dust application and this must be applied to damp foliage so that the fertilizer can stick to the leaves.

The best time would be after a shower of rain or early in the morning when there is dew on the foliage. Even so, dusts are not as efficient as sprays, because more of the material falls off the leaves on to the ground, and about twice as much fertilizer is required in the form of a dust to obtain as good an effect as a spray. A carrier, such as ground gypsum, can be used as an aid in applying a small amount of dust.

Sprays are used more often than dusts, especially when applying trace element fertilizers which are required in only very small amounts. The leaves absorb a considerable proportion of the applied nutrients in a few hours, but twelve hours of dry weather are usually considered to be the minimum time needed for a successful foliar treatment. If heavy showers of rain follow the application, most of the nutrient will be washed off the leaves.

TIME OF APPLICATION

Dusts or sprays should be applied as soon as there is a good leaf coverage of the ground, e.g., for cereals, when the plants are beginning to meet between the rows. When deficiency symptoms appear at a very early stage of growth, treatment should be given immediately, followed by a further application in two or three weeks, since most of the first application will have fallen on bare ground. For fruit, spraying can commence after petal fall. Both upper and lower surfaces of leaves should be sprayed, because absorption is greater through the under surfaces of leaves. Where a deficiency occurs every year in a particular field, irrespective of crop, e.g., manganese deficiency in the fens, it is better to apply the foliar treatment before symptoms appear.

PREVENTION OF LEAF SCORCH

It is difficult to eliminate entirely risks of leaf scorch damage when using nutrient sprays. Water on its own can cause scorching when there are unfavourable spraying conditions. Risk of scorch damage is less if the spray spreads evenly over the leaves and does not form large droplets. Fine mist sprayers should be used in preference to those which deliver large droplets, and leaf wetting can be improved by the addition of a spreader to nutrient sprays. There are many wetting agents on the market, each differing slightly in its wetting property. Modern wetting agents which have been found satisfactory in horticulture should be used; soaps should be avoided because some can cause precipitation of nutrients. Fairly rapid drying, in about a quarter of an hour, is essential because scorch can occur if the leaves remain wet for a long period after the spray application. Spraying should not be done when there are slow-drying, humid conditions. If the weather is hot and sunny, spraying should be carried out in the morning or late afternoon, or scorch damage may occur.

VOLUME OF SPRAY AND RATES OF FERTILIZER APPLICATION

Nutrient sprays are generally applied at the rate of 20-100 gal. per acre for agricultural crops. A low rate of application is possible only if the fertilizer supplying the nutrient is sufficiently soluble in water, and where the total amount of fertilizer applied per acre is the same as in a high-volume spray. Risks of scorch damage with low-volume spraying are, in general, no greater than when high volume is used, provided there are favourable spraying conditions. If spraying has to be carried out under poor conditions a high volume should be used because this spray is less concentrated. High volume is used when applying treatments to fruit and the rate of application varies from 100-400 gal. per acre, depending on the size of the trees.

The amount of fertilizer which can be applied in a spray depends on the tolerance of the foliage to the chemical compounds supplying the nutrients. Only small amounts can be recommended in advisory work, because of the danger of severe scorching if very concentrated solutions are used. The rates used are given in Table 2 under the individual nutrient spray headings, but fertilizers supplying the major element can generally be applied in sprays at the rate of 10-40 lb. per acre. The low rates are used for fruit and the high ones for agricultural crops. Rates of application of compounds of the trace elements vary from a few ounces to 10 lb. per acre.

PREPARATION OF SPRAYS

Finely-ground material should be used when preparing sprays, since small crystals dissolve more easily than large crystals. For example, both manganese and copper sulphates can be obtained in small or large coarse crystals and the fine material should be chosen. To ensure that the fertilizer is completely dissolved before the spray is applied, concentrated stock solution should be prepared and an appropriate proportion of it added through a strainer to the bulk of water in the spraying machine. Stock solutions should be prepared in wooden or enamel containers. This is essential when preparing a copper sulphate solution. If it is made in a galvanized container, interchange of metals between the container and the solution will occur, and zinc can be brought into solution in sufficient quantity to cause scorch damage of foliage. Where materials are only slightly soluble in cold water and have greater solubility in hot water, e.g., borax, the stock solution can be made more easily in hot water.

As information on the solubility of the materials used in sprays and on the preparation of stock solutions is often sought by Advisory Officers, the following table has been prepared as a *guide* for the preparation of sprays:

Table 2

Fertilizer	Element in Fertilizer	Approximate Solubility at 17°C	Suggested Stock Solution	Field Spray		
				Agricultural Crops	Volume	*Fruits
	per cent	*lb. per* 1 *gal. water*	*lb. per* 10 *gal. water*	*lb. per acre*	*per acre*	*lb. per* 100 *gal.*
Urea ($NH_2.CO.NH_2$)	44 (N)	10	30	20–30	20–100	5–10
Triple superphosphate	19.5 (P) (water soluble)	—	8	20–25	40–100	—
Sulphate of Potash (K_2SO_4)	40 (K)	1 2 at 75°C	8 (H)	30	40–100	5–10
Muriate of Potash (KC1)	49.5 (K)	3.4	20	20	20–100	—
Epsom Salts ($MgSO_4.7H_2O$)	9.9 (Mg.)	7	60	20–30	20–100	20
Manganese Sulphate ($MnSO_4.4H_2O$)	24.5 (Mn.)	10	32	5–8	20–100	3
Copper Sulphate ($CuSO_4.5H_2O$)	25.5 (Cu)	3	3	¾	20–100	½
Bordeaux Type (Copper Sulphate/ Hydrated Lime)	12.7 (Cu) in 1:1 type	—	4:4	4:4	50†–100	1:1
Copper oxychloride fungicide	45 (Cu)	—	—	2¼	50†–100	1
Cuprous oxide fungicide	48–52 (Cu)	—	—	2	50†–100	1
Borax ($Na_2B_4O_7.10H_2O$)	11.3 (B)	0.3 3.8 at 60°C	2 (H)	3	20–100	—
Boric Acid (H_3BO_3)	17.5 (B)	0.5 2.4 at 80°C	3 (H)	1½	20–100	—

*Apply at the rate of 100-400 gal. per acre according to the size of the tree.

†Limited experience with low volumes. (H) Dissolves more easily in hot water.

Foliar Application of the Major Elements

NITROGEN

Crop requirements can be supplied by nitrogenous fertilizer dressings applied to the soil as seedbed applications and as top dressings during the growing season, and there are few occasions where soil dressings are ineffective. There is considerable interest at present in the use of nitrogenous sprays for the top dressing of crops, particularly of cereals. However, there are no published results of experiments to show that a nitrogenous spray gives any better results than the same amount of nitrogen applied to the soil. As the method is more expensive and the

treatment is of temporary value only—due to the small amount of nitrogen that can be applied in a spray—there is no advantage in its use, except when there are unfavourable conditions for the rapid utilization of nitrogen applied to the soil. The method can be recommended when it is necessary to tide a crop over a period of bad growing conditions. For example, a nitrogenous spray can act as a useful means of stimulating growth in a very dry season when nitrogen applied to the soil cannot act due to lack of soil-moisture. Foliar treatment is also useful in controlling nitrogen deficiency in crops on very light soils, deficient in organic matter, when rapid leaching of nitrogen occurs in very wet seasons. During a very cold spring a nitrogenous spray can act more quickly than a nitrogenous fertilizer soil dressing, and a spray can be used as a supplement to the ordinary soil applications of fertilizers in order to obtain a rapid response.

Urea, which contains a high amount of nitrogen and is very soluble in water, is used in the nitrogenous spraying of crops. The amount of nitrogen which can be applied in a urea spray is much greater than in sprays using the more common nitrogenous fertilizers (sulphate of ammonia and nitrate of soda) which can give leaf scorch even in quite dilute solutions. Urea is broken down to ammonia and carbon dioxide by enzyme action in the leaves, and if the process is very rapid the ammonia can cause slight leaf-scorch. The spray used for agricultural crops is 20 lb. urea in 20-100 gal. water per acre. Up to 40 lb. urea per 100 gal. water to the acre can be used for cereals where a slight scorch, if it occurs, is not serious.

Urea sprays are sometimes used for the treatment of nitrogen deficiency in fruit trees when a soil application of a nitrogenous fertilizer would be ineffective. When nitrogen deficiency symptoms appear in a very dry season on soils low in organic matter, after a wet winter and spring, or during a cold spring, a foliar application of 5 lb. urea per 100 gal. of water can temporarily prevent the development of severe symptoms until soil dressings become effective. Dr. Bould, working at the Long Ashton Research Station, has reported benefit from the use of one to three sprays of 5-10 lb. urea per 100 gal. water, applied at fortnightly intervals after petal fall, in the year following grassing down of an apple orchard. In the Eastern Province some growers of apples on light sandy soils, low in organic matter, have reported better control of magnesium deficiency by adding 3 lb. urea to magnesium sprays.

PHOSPHORUS

A foliar application of phosphate is more effective than a soil dressing in preventing loss of yield when phosphorus deficiency develops in a crop because of inadequate application of a phosphatic fertilizer to the seedbed. Successful treatment of this deficiency in established crops has occurred in a number of instances in the province when 20-25 lb.

triple superphosphate have been applied in a spray at the rate of 40-100 gal. water per acre. Low-volume spraying below 40 gal. per acre is not possible owing to insufficient solubility of the phosphate in the fertilizer. A powdered triple superphosphate should be used because the granular material is much more difficult to dissolve. Ordinary superphosphate should not be used since it contains a substantial amount of calcium sulphate which is only slightly soluble in water and forms a sludge. A slight amount of sludge is formed in a triple superphosphate spray, but this has not been found to cause blockage of spraying jets if the stock solution is passed through a strainer as it enters the spraying machine.

A dust of $\frac{1}{2}$-$\frac{3}{4}$ cwt. powdered superphosphate per acre can be used as an alternative to a spray.

POTASSIUM

When potassium deficiency occurs in an established crop, foliar treatment is generally more efficient than a soil dressing for preventing serious loss of yield. A spray or dust should be given in preference to an ordinary top dressing of fertilizer. Serious potassium deficiency which cannot be controlled completely by fertilizer applied to the soil is often found in lucerne grown on light sandy soils in the province, and the foliar method has been found very useful in treating it. A spray or dust applied about two weeks after each cut may be required, in addition to a heavy dressing of potash applied to the soil in the autumn or spring.

Both muriate of potash (60 per cent) and sulphate of potash can be used in foliar treatment. The latter is the safer material and can be used at a slightly higher rate, but it has the disadvantage that it is less soluble in water. The sprays used for agricultural crops are 20 lb. muriate of potash in 20-100 gal. water per acre, and 30 lb. sulphate of potash in 40-100 gal. water per acre. Alternatively, a dust of either fertilizer can be applied at the rate of $\frac{1}{2}$ cwt. per acre. A more dilute spray is used for fruit in order to avoid any risk of scorch damage, and sulphate of potash at the rate of 5-10 lb. per 100 gal. water should be used instead of muriate of potash. The method can be used when deficiency symptoms appear in fruit crops and it is necessary to prevent the development of more serious symptoms of the deficiency during the remainder of the season. From one to three sprays may be required in the first season as a temporary means of controlling the deficiency until soil dressings become effective.

MAGNESIUM

Probably insufficient attention is paid to the magnesium nutrition of agricultural crops growing on the light sandy soils of the province, where cash cropping is practised with consequent removal of sub-

stantial amounts of magnesium from soils which have low reserves of magnesium and nitrogen. (Magnesium deficiency generally is worse where the nitrogen nutrition of the crop is poor.) It is not surprising therefore that from slight to severe magnesium deficiency symptoms often occur early in the season in cereals and sugar beet in these areas. Symptoms usually disappear as the season progresses and this probably explains why experimental workers have paid little attention to the deficiency until the last two or three years. The problem may become more acute as heavy cropping continues on these soils and the application of magnesium, either as soil or foliar dressings, may become essential for maximum crop production. The application of kainit, containing substantial amounts of magnesium, should be encouraged for beet crops on these soils. Where acute magnesium deficiency symptoms develop early in the season in cereals and beet, a foliar spray should be applied. Where the deficiency occurs in potatoes, carrots and vegetables, magnesium treatment is essential to prevent serious losses of yield. The recommended spray is 30 lb. Epsom Salts in 20-100 gal. water per acre; one application usually is sufficient for agricultural crops and vegetables. Further field experiments are required comparing soil and foliar dressings of magnesium to find the most efficient method of preventing the deficiency in crops grown on magnesium-deficient soils.

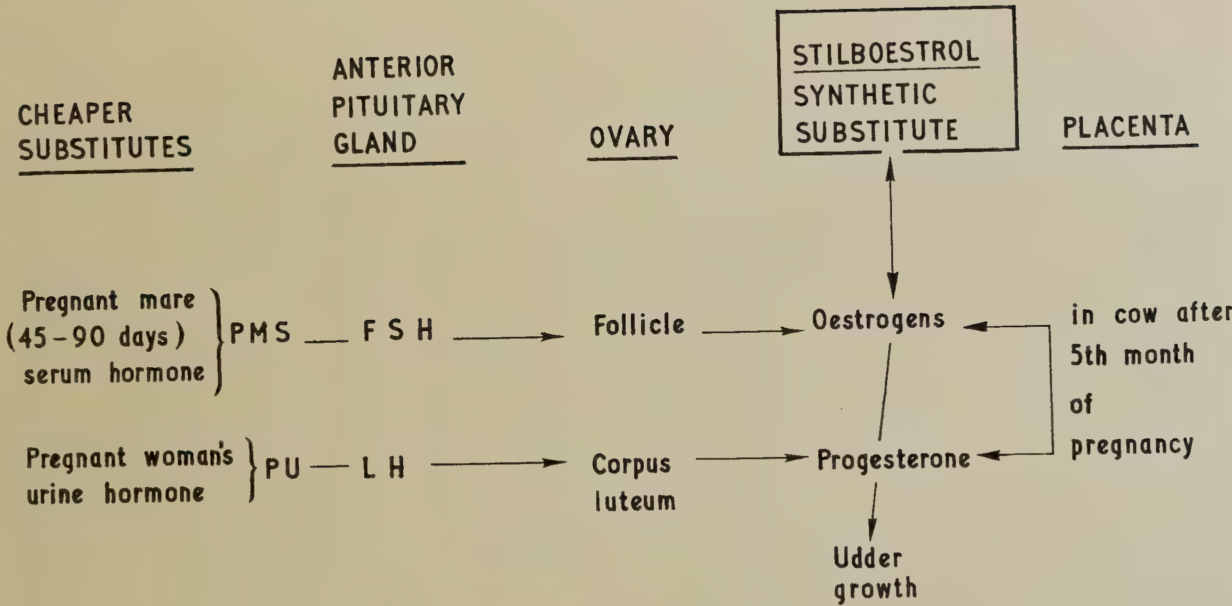
Magnesium deficiency is a fairly common problem in fruit and glasshouse crops. It is essential to establish the cause of the deficiency, since it quite often occurs where there is no shortage of magnesium in the soil. Bad soil conditions, such as poor drainage or pan formations causing poor rooting, can induce deficiencies, particularly magnesium deficiency. Heavy dressings of potash applied to the soil can also do this and a careful watch must be kept on potash manuring of fruit and glasshouse crops. Under the conditions mentioned, magnesium applied to the soil may have very little effect in controlling symptoms in the crop. Foliar treatment has to be used until soil conditions are improved, or, where there is excess potassium in the soil, until the level of potash manuring is reduced. Recovery of trees is usually slow, and foliar treatment may be required for a number of years. The spray used is 20 lb. Epsom Salts per 100 gal. water and several fortnightly applications may be needed after petal fall.

Where the deficiency occurs in fruit owing to lack of magnesium in the soil, a combination of soil and foliar treatments is required in the first two or three seasons. A heavy application of Epsom Salts (4-6 cwt. per acre) to the soil, plus a number of foliar sprays are necessary the first year. In the next two years, the soil dressing can be reduced (2 cwt. per acre) and fewer foliar applications will be required. When the trees have recovered from the deficiency an occasional soil dressing should be sufficient.

HORMONES IN FERTILITY (see pp. 227-31)

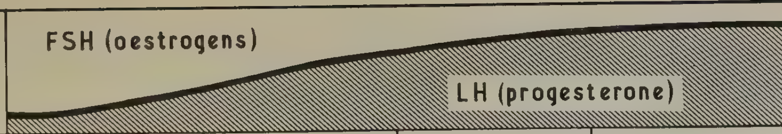
Two crops of lambs a year. This photograph, taken in October, shows half-bred ewe lambs which were injected with progesterone followed by PMS, were served at the end of April, and lambed at the end of September. They took the ram again during that season and lambed the following spring.

PLATE I



The relation between two hormones of the anterior pituitary gland (FSH and LH) and the sex hormones formed by the ovary and placenta, their action and cheaper sources of supply.

PLATE II

ANTERIOR PITUITARY				
SPECIES	Mare	Sow	Ewe	Cow
DURATION OF OESTRUS (hr.)	144	72	24	16
OVULATION (hr. in relation to end of oestrus)	38 (before)	4 (before)	0 (after)	14 (after)
"SILENT HEATS" ※	Rare		Frequent	

※ The occurrence of ovulation at the normal time without the symptoms of oestrus.

Effects on the oestrous cycle of the relative amounts of follicle-stimulating hormone (FSH) and luteinizing hormone (LH) in the anterior pituitary gland.

PLATE III

FARM MECHANIZATION IN THE WEST MIDLANDS

(See pp. 268-73)

Hand labour on sugar beet. Unsoiled tops are a valuable asset.

Alternate rows of lucerne and cocksfoot sown by modified multi-purpose drill.

PLATE IV

Foliar Application of Trace Elements

IRON

Treatment of iron deficiency symptoms in crops by foliar application of iron salts has given very little success. There is rapid immobilization of the iron absorbed by leaves and little or no movement of the nutrient to the growing regions. An iron sulphate spray can cause very severe scorching and gives only localized greening of leaves. No spray or soil treatment on a field scale has been found so far that can be used effectively, or be recommended in advisory work. Fortunately, serious iron deficiency has not been found in agricultural crops, but it has been observed in the Province in chalky marl patches in sugar beet and lucerne fields.

Very severe iron deficiency occurs in fruit on many of the chalky soils of the Province. The injection of iron sulphate pills into the trunks of trees is used occasionally for the treatment of the deficiency in top fruit, together with cultural operations such as the improvement of soil conditions, and where possible, the grassing down of orchards. No treatment on a field scale is possible at the moment for controlling the deficiency in bush fruit and strawberries.

Recently, organic compounds containing iron have been used in sprays and soil applications on a research and experimental scale. These compounds are known under various names, for example iron chelates, Fe EDTA (the iron chelate of ethylene-diaminetetraacetic acid) and various trade names. The term chelate describes in chemical language the way in which the iron is combined with the organic part of the compound. More success has been obtained with iron chelates than with inorganic iron compounds in the treatment of a limited number of crops. However, the addition of chelates to a chalky soil in sufficient quantity to control symptoms in crops is very expensive, and cannot be advised except for small-scale work. Varying degrees of success have been obtained on a few crops by using sprays of ½-1 lb. iron chelate per 100 gal. water, but at present the method can only be considered in advisory work for treatment on an experimental scale.

The control, on a commercial scale, of iron deficiency symptoms in crops remains a major problem in crop nutrition.

MANGANESE

Manganese deficiency can be treated successfully by foliar application of manganese sulphate. Foliar treatment is more efficient than soil applications because larger quantities of manganese sulphate (½-1 cwt. per acre) applied to the soil are needed to obtain as good an effect as a small amount in a spray. In addition, it is difficult to predict the degree of response that will be obtained by a soil application.

The spray used for agricultural crops is 8 lb. manganese sulphate in 20-100 gal. water per acre. Mustard is apparently very sensitive to solutions of manganese sulphate and severe scorching often occurred

where this rate was used. The spray recommended for this crop is 5 lb. manganese sulphate per 100 gal. of water per acre. The concentration of the spray is reduced to 3 lb. per 100 gal. water for application after petal fall to fruit.

As a rule, one application of the spray is sufficient to control the deficiency. Two applications are sometimes required when the deficiency is severe in cereals and potatoes. Reduction in yield of potatoes is inevitable if deficiency symptoms are allowed to develop before treatment. For winter-sown cereals on severely affected land, it may be advisable to apply a late autumn spray as well as the normal spray in spring.

Manganese can be applied in a dust of 20-30 lb. manganese sulphate per acre. This method is not often used because of the difficulty of applying such a small quantity per acre, but it is useful where the deficiency occurs in small patches. Sometimes these are found alongside areas of very acid soil—for instance in the fens—and an application of manganese to the whole field may bring out manganese toxicity effects in the very acid areas. Dust can be applied by hand to the manganese-deficient areas.

COPPER

Copper deficiency has often been found in the past eight years in cereal crops grown on both acid and alkaline peats, and on light, sandy, reclaimed heathland soils in the Province. In experiments initiated by Dr. Pizer on various methods of treating copper deficiency in these areas, it has been found that control can easily be obtained by sprays of various copper compounds. Copper sulphate can be used at the rate of $\frac{3}{4}$ lb. in 20-100 gal. water per acre for cereal crops. Slight scorch generally occurs with a copper sulphate spray but is not serious for cereals. More copper can be applied with advantage and in a safer way, if hydrated lime is added to a copper sulphate spray to make a Bordeaux-type of nutrient spray. Rates of application are 4 lb. copper sulphate plus 4 lb. hydrated lime per 100 gal. water per acre. Fungicide materials, such as those based on cuprous oxide and on copper oxychloride, can be used as copper nutrient sprays at the rate of 2-2$\frac{1}{4}$ lb. material per 50-100 gal. water per acre. Straight copper sulphate washes off leaves easily, but fungicides are very insoluble and the copper becomes slowly available to the crop over a longer period of the growing season. One copper spray is sufficient to control the deficiency in cereals unless the spray has to be applied at a very early stage, when much of it falls on the soil.

In the experiments mentioned in the previous paragraph, it has been found that sugar beet growing on soils where copper deficiency occurs in cereals, responds to copper treatment. A foliar application of 2-2$\frac{1}{2}$ lb. of copper fungicide in 50-100 gal. water per acre can increase the acreage yield of sugar. If a copper sulphate spray is used on sugar beet, a slight check of growth can occur because of leaf scorch.

Copper deficiency has not been found in fruit in the Province, but it occurs in other regions. Foliar treatment consists of an application after petal fall of $\frac{1}{2}$ lb. copper sulphate per 100 gal. water. The addition of an equal weight of hydrated lime can improve the spray and prevent scorch damage, and the rate of application can be increased to 1 lb. copper sulphate plus 1 lb. hydrated lime per 100 gal. water.

BORON

Boron deficiency is controlled by a seedbed application of 20-30 lb. borax (sodium borate) per acre, and there is little evidence to suggest that a foliar treatment would be more effective. The latter can be used when the deficiency is observed in an established crop and where it would be too late to obtain a rapid effect from borax applied to the soil as a top dressing. The deficiency must be diagnosed at an early stage if the treatment is to be successful. If diagnosed at a late stage it is very difficult to arrest the plant tissue breakdown, especially if pathogens have invaded the decayed tissues. For agricultural crops, a spray of 3 lb. borax in 20-100 gal. water per acre can be used before severe symptoms occur. When boron is required in a spray in addition to one of the other trace elements, e.g., in diagnostic work, boric acid is used instead of borax at the rate of $1\frac{1}{2}$ lb. per 100 gal. per acre, because chemical reaction can take place between borax and the sulphates and result in the formation of less soluble borates.

Mixed Sprays

Nutrients can be applied with each other, provided that the total concentration of the combined fertilizers in the spray does not reach a level where leaf damage occurs. The amounts of the major elements that can be combined together in a complete spray are small, and so no appreciable benefit may occur from one application of the combined spray. A combination of trace elements in one spray applied at 100 gal. per acre is possible without reductions in the amounts of the nutrients when used singly. However, multiple deficiencies of trace elements have not been found so far in the Province, and the combination of several nutrients is best reserved for experimental work in the diagnosis of deficiencies. The only combination of trace element deficiencies which has been found in any number are copper and manganese, which occur together in some of the peaty fen soils of the area.

Nutrients can be added to sprays used for the control of weeds, pests and diseases where no chemical reaction or change in the solubilities of the constituents of the spray occur. It is not possible to give a list of sprays to which nutrients can be added, because the formulation of materials such as the weed-killing chemicals often change from year to year. Addition of nutrients to herbicides, etc., should be done only where the manufacturer of the latter states that it is possible. Epsom

Salts should not be mixed with lead arsenate used in fruit spraying because the increased solubility of the arsenate can cause leaf scorch and defoliation. It is dangerous to apply a manganese sulphate spray directly after a Bordeaux Blight spray or dust, because the solubility of the copper in the Bordeaux mixture may be increased to a level where severe scorching of leaves can occur.

The observations and recommendations in this review of rates of application of the various nutrients have been based mainly on experience and experimentation in the diagnosis and treatment of deficiencies in crops in the Eastern Province. The rates may require modification in other regions where climatic and growing conditions are different from those in this area.

Nutritional Aspects of Hay

Composition of Meadow Hay

An interesting report [1] has just come from Cockle Park on the composition of meadow hays produced on plots which have received unaltered manurial treatment for almost sixty years. Thirteen of such plots are listed, each one with a different treatment, but, for lack of space, only four can be detailed here:

Plot No.	Annual Treatment per Acre	*p*H	Available P_2O_5	Available K_2O
			per cent	*per cent*
2	8 tons farmyard manure	5.7	0.016	0.015
6	Unmanured	5.1	0.005	0.014
8	300 lb. basic slag	5.8	0.011	0.008
13	150 lb. sulphate of ammonia, 300 lb. basic slag, 100 lb. muriate of potash.	5.3	0.023	0.013

Analysis of the hays produced gave the following results, the figures being expressed as percentages of the dry matter. The figures in brackets are percentage digestibilities determined by feeding sheep with the chopped hays shown in the table overleaf.

	Plot 2	Plot 6	Plot 8	Plot 13
Organic Matter	94.0 (61)	94.3 (62)	93.7 (63)	94.8 (61)
Crude Protein	7.0 (47)	8.1 (53)	8.0 (50)	7.6 (52)
Oil	1.7 (57)	1.6 (54)	1.8 (56)	1.7 (57)
Crude Fibre	32.0 (64)	26.6 (61)	28.4 (65)	29.8 (63)
Soluble Carbohydrates	53.3 (61)	57.9 (65)	55.6 (64)	55.7 (62)
Cellulose	41.4 (65)	38.7 (66)	38.5 (70)	42.0 (68)
Lignin	8.2 (4)	7.9 (4)	8.6 (15)	7.9 (6)
Calculated Starch Equivalent	40.0	43.6	43.4	44.5
Digestible Crude Protein	3.3	4.3	4.0	4.0
CaO	0.62	0.97	0.87	0.72
P_2O_5	0.55	0.33	0.58	0.55
MgO	0.12	0.23	0.21	0.16
K_2O	1.78	0.98	0.74	1.12

Note: The sum of 'cellulose' and 'lignin' exceeds the figure for 'crude fibre' by about 20 per cent in each case. The latter material is, of course, what remains of the two former after treatment with boiling acid and alkali.

The outstanding finding, indicated above and shown more clearly in the complete table of the thirteen hays, is that the best compositions are allied to the worst treatments. Hay No. 6, which received no treatment whatever, had the highest protein, the highest lime, the second highest magnesia, and the lowest fibre. However, it had the third lowest phosphate, and low phosphate in a hay is very undesirable. It is known that the activity of ruminal microbes depends upon adequate phosphate, and it may not be without significance that the best and worst digestion of crude fibre and lignin in the above table is associated with the highest and lowest phosphate.

It should be said that the quantity of hay per plot was less where the quality was higher. Thus Plot 1 which received a dressing of dung plus balanced artificials, yielded over two and a half times as much hay as the unmanured Plot 6.

The authors' comments on the relation between treatment and composition are briefly as follows. Basic slag raised the fibre of the hays and dung did it even more. Protein was highest where manuring was absent, or consisted only of N and/or K. Basic slag was intermediate in its effect on protein, and dung, with or without artificials, gave the lowest proteins. Lime was very low where only N or N+K was used, low in every dunged plot, and satisfactory wherever slag had been applied.

Seeking for explanations for some of the apparent anomalies, the authors point out that all plots were cut on the same day. The poorer grasses would therefore be less mature (and consequently of better compositional quality) than grasses such as ryegrass; also, the effect of phosphate in advancing maturity should be remembered. Probably the main factor was herbage species difference. Thus, Plot 1 (dung plus

artificials) contained 90 per cent grasses, 2.3 per cent clovers and 1.8 per cent weeds, while Plot 9 (muriate only) had 75 per cent, 6.9 per cent and 14.3 per cent respectively; Plots 6 (nil) and 7 (sulphate of ammonia) were similar to 9. Ribgrass (*Plantago lanceolata*) and yellow rattle (*Rhinanthus crista-galli*) were present in quantity in the latter plots and these plants are high in lime and low in fibre.

The work supports the view that 'herby' meadow hay, grown without much attention on some farms, is often able to maintain its quality over many years; low yields rather than low quality conserving the store of soil nutrients.

Digestion of Phosphorus

Mention has been made of phosphate in hay. It may be of interest to consider some American work [2] on the availability of phosphate in lucerne hay. Since phosphate after use is normally excreted from the body tissues via the intestine, it has never been possible until recently to distinguish in the faeces between 'digested' phosphate reappearing after use, and 'undigested' phosphate which has never been absorbed at all. However, this distinction can now be made by the use of a technique employing a radioactive isotope of phosphorus. The American workers showed that lambs were able to digest and absorb as much as 90 per cent of the phosphate in a sample of lucerne hay, although the 'apparent' digestibility (as measured by the difference between phosphate in food and phosphate in faeces) was only about 25 per cent. Radiophosphorus has also been used to locate the site of absorption of phosphate from the alimentary canal of the sheep [3]. Absorption from the rumen, omasum and colon was found to be negligible compared to that from the abomasum (true stomach), where the effect was 100 times greater, no doubt due to the solvent action of the acid gastric juice in the latter organ. Absorption from the ileum was also important; there it was one-tenth of the abomasal amount, but ten times that of the ruminal. For some unexplained reason the duodenum was not found to absorb phosphate, although this part of the gut receives the acid digesta from the abomasum and in consequence has itself an acid reaction.

American Feeding Value Experiments

A test has been described [4] of the relative abilities of hays averaging 95 per cent lucerne and others averaging 55 per cent lucerne plus 44 per cent timothy to provide for the growth of heifers when given *ad lib* as the sole food (apart from extra minerals) for four months. The hays rich in lucerne were the most efficient, but it was thought that the differences could not be ascribed merely to the greater amount of protein, because continuation for another month, during which time half the animals in each group were given extra protein or extra minerals, made no significant changes in the growth rates. The possibility that carotene

might be a factor was discounted on the grounds that the blood of all the animals seemed adequately furnished with carotene and vitamin A. The main findings are summarized in the following table:

Group No.	Average Daily Liveweight Gain *lb.*	D.M. Eaten per Day *lb.*	Timothy *per cent*	Protein *per cent*	Fibre *per cent*	Carotene p.p.m.
A	2.00	19.2	0.0	22.5	22.8	51.6
C	1.79	19.0	0.0	21.7	23.3	30.2
B	1.41	18.0	0.0	16.9	30.8	11.6
F	1.18	15.3	24.8	15.8	33.9	6.2
D	0.82	14.8	44.1	12.7	36.7	10.2
E	0.73	15.1	62.9	10.1	35.4	5.3

Another American paper [5] deals with the effect on milk production of varying the rates of hay feeding. Rates of hay were established at 0.50, 1.17, 1.83 and 2.50 lb. daily per 100 lb. live weight; the hay contained 11.7 per cent protein and 30.3 per cent fibre. The remainder of the ration was a concentrate made up of 50 parts ground maize, 35 ground oats, and 15 of extracted soya bean meal, with 3 parts of minerals. Each complete ration (hay plus concentrates) had its T.D.N. (total digestible nutrients) content adjusted in accordance with the live weight of the cow and the level of milk production observed during a preliminary feeding period. It was found that digestibility decreased as the proportion of hay increased; but, if the T.D.N. content were kept constant in the ration by adjustment of the concentrate moiety, there was no significant alteration of milk yield or live weight. When E.N.E. (estimated net energy) was used instead of T.D.N. as the basis of calculation, it was not found to be significantly superior but was perhaps slightly more consistent. Another paper [6] in which part of the hay was replaced by concentrates equivalent on either a T.D.N. or E.N.E. basis showed that both seemed to overrate the value of the hay, but that the E.N.E. did so to a lesser extent.

The last paper [7] describes attempts in America to determine the optimum amount of hay to be added to a maize silage—concentrate ration. Forty-four of the sixty cows used were Jerseys. The concentrates were mixtures prepared for milk production (no details of composition were supplied) and they were fed at the rate of approximately 2½ lb. per gallon. The maize silage was given *ad lib* three times a day. The lucerne hay was offered at one or other of 4 levels, viz., 1.0, 0.5, 0.25 and 0.00 lb. daily, per 100 lb. live weight. A typical set of results is shown overleaf.

	Hay offered per 100 lb. live weight (lb.)			
	1.00	0.50	0.25	0.00
Dry matter obtained from concentrates . . .	7.6	8.0	7.4	7.5
Ditto hay	6.9	3.9	1.9	0.0
Ditto silage	11.2	13.2	13.5	14.1
Total dry matter .	25.7	25.1	22.8	21.6

Maximum dry matter intake was calculated to occur at about 0.8 lb. of hay per 100 lb. live weight. The optimum for milk and fat production was just over 0.5 lb. hay per 100 lb. live weight. The percentage of fat was unaffected and there were no significant alterations in live weight.

Hay, Concentrates and Milk Quality

Much work has been done in England on the importance of hay in rations for milk production and some of it has already received attention in this REVIEW (No. 26, Winter 1954, p. 77). Two more papers [8] in the series have now appeared.

The first of these deals with the effect on milk yield and composition of two different concentrate mixtures fed with small quantities of lucerne-cocksfoot hay. Some of the data relating to the rations are now given :

'Cubes'—Wheat feed 20; barley meal 25; maize meal 5; molasses 7.5; extr. decort. sunflower meal 10; sugar beet pulp 5; undecort. cotton cake meal 12.5; copra cake meal 7.5; vegetable protein conc. 7.5.

'Mixture'—Flaked maize 50; wheat feed 35; decort. ground nut meal 15; plus minerals at 1 lb. per cwt.

	Protein *per cent*	Fibre *per cent*	Cellulose *per cent*	Starch *per cent*
Hay	11.4	30.0	30.8	0
'Cubes' . . .	16.2	9.6	13.8	16.3
'Mixture' . . .	15.9	4.6	9.4	30.5

The differences in fibre and starch contents of the two concentrates will be noted.

The feeding programme was as follows:

I. For the first four weeks the cows received 20 lb. hay per day plus 'cubes' at the rate of 4½ lb./10 lb. milk.

II. During the 5th week the hay was gradually reduced to 4 lb. and the cubes increased by 6-10 lb. (appetite was a limiting factor in adjusting the amounts of cubes). This level was maintained for the 6th and 7th weeks and during this time there was no decrease in the fat percentage of the milk.

III. For the 8th to 13th weeks, the 'cubes' were replaced by 'mixture' and there was a fall in fat percentage which became evident in 24 hours. The mean fall, measured during weeks 11 and 12, was 1.04 per cent. (It may be remarked that, while care was taken to make the change from I to II a gradual one, the change from II to III appears to have been abrupt.)

IV. Finally, the hay was again raised to 18 lb. and the 'mixture' given at the rate of 4-5 lb./10 lb. milk produced. This resulted in a restoration of the fat percentage to the original value. The S.N.F. was the same in periods I and II but rose by an average of 0.48 per cent in period III, a rise due entirely to an increase in protein. The S.N.F. fell again in period IV over five weeks to a figure about 0.1 per cent above the original.

It will be seen that 'cubes' and 'mixture' behaved similarly when accompanied by 18-20 lb. of hay. In the presence of only 4 lb. of hay, the difference in the effects of 'cubes' and 'mixture' is no doubt to be ascribed to the much greater amount of digestible starch in the latter. Flaked maize in particular is known to have a marked effect on rumen bacteria. Interference with the normal flora can upset the production of fatty acids from which milk fat is made.

The second of the two papers by the Shinfield workers investigates further the influence of flaked maize and compares it with maize meal and dredge corn. The rations were as follows:

	Mixture X	Mixture Y	Mixture Z
Decort. groundnut cake	15	15	15
Weatings	35	35	35
Flaked maize	50	—	—
Maize meal	—	50	—
Ground dredge corn (oats 55, barley 45)	—	—	50

The percentages of some of the constituents were:

	Protein	Fibre	Cellulose	Starch
Hay	6.9	29.3	35.3	—
Mixture X	16.4	4.5	7.0	32.7
„ Y	16.3	4.7	9.9	32.6
„ Z	15.6	7.3	12.4	25.3

The feeding was as follows:

I. *Weeks 1 to 3.* All cows received 16 lb. hay daily, plus 4 lb. of X for each 10 lb. milk produced.

II. *Weeks 4 to 9.* During weeks 4 and 5 all rations were changed gradually. The hay was reduced to 4 lb. and the reduction made good by 7 lb. extra concentrates. One-third of the cows still received mixture X, but the second third received Y, and the remaining third Z. X was given at 4 lb. per 10 lb. milk, Y at 4.2 and Z at 4.8 to ensure equal intakes of S.E.

III. *Weeks 10 to 13.* During the 10th week hay was increased to 16 lb. daily and concentrates were reduced and also changed back to X at the 4 lb. rate for all cows.

In period II, the yield of cows receiving X fell to a significantly lower figure than those getting Y and Z. In period III the rate of fall was checked and there were no marked differences between the three groups. The fat percentages fell with both the maize rations X and Y so that in II they were 0.71 per cent and 0.20 per cent respectively below that for the dredge corn ration Z. The latter ration was without effect on fat percentage. In contrast to the findings in the previous paper, the treatments here had no effect on S.N.F. percentage.

This experiment showed that in rations with the same low amount of fibre and with similar amounts of starch, the *nature* of the starch determines whether the milk fat percentage will be affected. The possibility is not excluded that starches other than those of flaked maize and maize meal may cause depressions in milk fat percentage, especially if very large amounts of concentrates are fed.

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S.M.B.

Dairy Husbandry

Housing Dairy Cattle

In the last two or three decades there has been a steady increase in the number of farmers in the United Kingdom who house their dairy herds in covered yards, and milk them in milking 'parlours' or fixed bails. Opinion is, however, divided on the relative advantages and disadvantages of this system compared with the conventional 'tie-up' cowhouse. In general, there is a strong case for the yard and parlour system for the large herd and for the conventional cowhouse for the small herd, but controversy tends to become more acute in the case of the medium-sized herd. It is therefore not surprising that in the United States, where a high proportion of the herds are on family farms with 20 or 30 cows, much study and discussion has been devoted to this problem. R. C. ANGUS and W. L. BARR (*J. Dairy Sci.*, 1955, **38**, 391) have recently reviewed and appraised, under five main headings, the principal papers concerned with the subject.

Construction costs. Initial construction costs were generally lower for covered yards (called loose-housing in the United States) than for conventional cowhouses.

Food consumption and milk production. A comparison of the two systems of housing showed that differences in milk production, food consumption and the sanitary quality of the milk produced were generally very small. Some cattle housed in covered yards consumed a little more bulky food.

Bedding and cleanliness. Substantially more bedding was used in covered yards, although the estimates ranged from 100 to 340 per cent of cowhouse consumption. The amount of bedding needed in covered yards can be reduced by having separate bedding and feeding areas and by planning the layout to reduce cow travel on the bedding. Generally, the cows appeared to be cleaner in covered yards than in cowhouses.

Labour. The covered yard system, on average, needed only about 80 per cent of the labour time required for the conventional system, and this saving was spread over all the major phases of the work—milking, feeding, bedding and cleaning. Sometimes, however, bedding and cleaning work took more time in the covered yard system than the cowhouse.

Cattle handling. A lower incidence of injuries, such as udder damage, lameness and sore feet was commonly observed in covered yards, where easier observation of oestrus was possible, but a number of investigators noted that the system reduced the opportunity for attention to individual cows and made the control of bulky food difficult.

Cleaning of Milk Equipment

Since before the war, labour costs have increased more rapidly than any other major item of expenditure on milk production. All aspects of milk production involving much labour are therefore of current interest. AKAM (*J. Soc. Dairy Tech.*, 1955, **8**, 94) found that the cost of cleaning and sterilizing milking equipment in herds of about 15 cows varied from 1*d*. to 3*d*. per gallon of milk, labour being the largest single item involved. A method of cleaning equipment which reduces labour, and at the same time other items of cleaning costs, has recently been developed and tried out on a number of commercial farms by the National Institute for Research in Dairying (C. C. THIEL, P. A. CLOUGH and L. F. L. CLEGG, *J. Dairy Res.*, 1955, **22**, 156). The method is mainly appropriate for 'direct-to-can' milking and consists essentially of immersion of all parts which come into contact with the milk in a cold caustic soda solution for the whole period between milkings. With no brushing or steam sterilization it was found possible to produce consistently milk of good quality, although the bacteriological standard of the clusters was not up to current standard and further work on this aspect was required.

Bloat

Bloat continues to take a steady toll of cattle in many countries where there is intensive dairy farming. In New Zealand, a survey of losses carried out on 25,311 herds during the period August 1953 and January 1954 (*N.Z. Dairy Board*, 30th Ann. Rept., 1954, 69) showed that one cow in every 200 died from bloat during the period. It is emphasized that, in addition to the deaths, labour time is used in dealing with those animals which recover, and losses in production are also involved in these animals during blowing. The incidence of death from bloat was found to vary widely from one district to another.

Further evidence about the causes of bloat has been put forward by W. S. FERGUSON and R. A. TERRY (*J. Agric. Sci.*, 1955, **46**, 257) as a result of work at Jealott's Hill. It was found possible to produce bloat in both cattle and sheep when they were dosed with lucerne juice. Administration of the flavone *quercetin* which inhibits the activity of smooth muscle failed to cause bloat, and the authors conclude that flavones are probably not involved in bloat. Formation of a stable foam appeared to be an important factor in lucerne bloat, but on fractionation the lucerne saponins did not appear to cause bloat. Foam-breaking compounds appeared to be very effective in relieving the condition. The role of lucerne saponin in bloat was also investigated by American workers (H. W. COLVIN, P. T. CUPPS and C. R. THOMPSON, *J. Dairy Sci.*, 1955, **38**, 606) who, using larger doses—100 g. per sheep per day in 1 litre of 5 per cent glucose solution—found that it stopped rumen motility, produced foamy bloat and in some cases resulted in the death

of sheep. Other research workers (J. T. Blake, N. L. Jacobson and R. S. Allen, *J. Dairy Sci.*, 1955, **38**, 606) also produced acute bloat with the juice of freshly-cut lucerne, and mild bloat with the spray-dried juice. Substantial changes in the basal diet of their animals failed to effect critical changes in the action of the lucerne juice.

Conception Rate and Pre-natal Mortality

The optimum time of service after calving has formed the subject of many previous studies, but very often the results are based on data collected from a herd or herds irrespective of the reproductive health of the cattle concerned. In a recent study in New York State, Trimberger (*J. Dairy Sci.*, 1954, **37**, 1042) compared the conception rates in three groups of fifty cows all known to be normal in genital health and to have had a normal calving. In one group the first service took place within 60 days, in a second between 61 and 90 days and in a third, over 90 days after the previous calving. The conception percentages were respectively 48, 70 and 76 per cent to first service, indicating that early service after calving may substantially reduce conception to first service.

Further evidence on the rate of pre-natal mortality following artificial insemination and pregnancy diagnosis by rectal palpation has been presented by Fosgate and Smith (*J. Dairy Sci.*, 1954, **37**, 1071) from data from the University of Wisconsin herd. Of 690 animals diagnosed pregnant, 44 or 6.38 per cent failed to remain in calf to 239 days after insemination. There was no significantly higher rate of pre-natal mortality at any particular stage of pregnancy.

A.S.F.

Migratory Root Eelworms

Much has been written in the last few years on the group of eelworms now known collectively as migratory root eelworms. Sometimes the eelworms, of various genera and species, invade the roots of plants causing poor growth and root rots; they also feed externally on the roots and terms such as 'sting' nematode and 'awl' nematode have been used for those with such habits.

Some of the earliest work on the subject was that of Steiner (1945) who described the effects of the Meadow Nematode (*Pratylenchus* sp.) on the root systems of maize, and the production of disfiguring black spots on peanuts. In 1949, Viggors and Tarjan reported a root disease of Pin Oaks in the U.S.A., which involved widespread killing of the root hairs and fibrous roots of the trees; they concluded that the trouble was possibly due to the presence of eelworms of the genera *Hoplolaimus* and *Pratylenchus*.

Brooks and Christie, in 1950, described a new trouble of Strawberries, associated with the nematode, *Belonolaimus gracilis* which proved to be largely ectoparasitic. Affected plants became semi-dormant and all new growth practically ceased. The edges of the leaves became dark brown, the plants declined over a period of weeks and finally died. Due to the continued attack on the roots and their partial replacement by the plant, the root systems were typically composed of coarse roots with knobbly tips. Since then, Lownesbery, Tarjan and others have carried out further work and have described a number of other genera and species of nematodes feeding on the roots of a variety of plants in a similar way. It would appear that there is often a complex of several nematode species involved. In particular, attention was focused on celery, and many observations were also made on the 'decline' of a variety of ornamental plants.

Changing Concepts of Parasitism

In the course of a paper on *Changes in Basic Concepts in Plant Nematology*, Steiner, in 1953, emphasized the importance of the new concept concerning the parasitism of nematodes in and on plants. 'To-day,' he says, 'the concept of parasitism of nematodes in plants equally embraces endo- and ecto-parasitism and includes that type of ecto-parasitism which is called planositism. In the case of plant nematodes the term applies to those forms which feed on roots from the outside and migrate from place to place, from root to root. This kind of parasitism, once completely ignored in plant nematodes, is of wide occurrence.' Steiner also referred to the increasing realization that nematode troubles are often caused by the presence of multiple infections and mixed populations. The so-called stimulation of crops produced by nematicidal soil fumigants may frequently be the result of an ignored control of multiple infections, instead of the single infection and pure populations assumed by the experimenter.

Much recent work has been carried out on these nematode problems by Oostenbrink and Besemer (1953) and Oostenbrink (1955). The first paper deals with root disease in fields devoted to the culture of cut flowers. Here was found a complex of Root-knot Eelworm (*Meloidogyne*), Meadow Nematode (*Pratylenchus*) and 'sting' nematodes (*Hoplolaimus*); these latter eelworms live ecto-parasitically with only their heads inside the roots. *Hoplolaimus* was sometimes found to build up to very high populations in the soil. Inoculation proved that the eelworms played a primary part as a cause of the disease, but the role of each species was not decided and fungus attack probably contributed. Soil fumigation with chorpicrin and DD gave a good control of the nematodes and it was concluded that soil fumigation would show a good return. Oostenbrink in 1954 described a simpler form of an ingenious apparatus devised by Seinhorst. With this apparatus it is possible to collect a large percentage of nematodes living free in the soil, and the use of such apparatus opens the way to more exact studies of these problems.

Nematodes in the Netherlands

Later work by Oostenbrink (1955) confirms that the various migratory root eelworms (*Pratylenchus*, *Paratylenchus*, *Hoplolaimus* and perhaps other species), play an important role in the agriculture and horticulture of the Netherlands. Poor root growth and rots have occurred in carrots, vegetables, ornamentals, grass, cereals and potatoes. Sickness symptoms in nursery stock are often caused by *Pratylenchus penetrans*. Fumigation with DD, or heating the soil to 60°C, to kill the nematodes, eliminated the growth-inhibiting factor in all cases. *P. pratensis* damages cereals and other crops, and *P. penetrans* damages nursery stock and potatoes. Crop rotation is obviously an important measure in the control of these nematodes. Cereals are not damaged by this latter species (*P. penetrans*), though there is evidence that they keep the populations at a high level. This explains why rotation with cereals has not checked the symptoms in potatoes and nursery stock. Random sampling of soils has shown that light concentrations of these eelworms are widespread in several countries. Certain conditions seem to build up these populations to a high enough level to cause disease symptoms.

Although reference has only been made to some of the papers which have been written on this subject, sufficient has been set down to suggest that much more attention needs to be given to the problem of migratory eelworms in this country. Several workers have concerned themselves with root rot in narcissus bulbs associated with *P. pratensis*, and Stone (1953) has published work on this eelworm in relation to root damage in delphiniums. Often general bad health of no obvious cause may well prove to be due to attacks by ecto-parasitic eelworms on the roots.

L.N.S.

Farm Management

Economic Principles of Farm Management

The dearth of British literature on farm management economics is compensated in part by the steady stream of new and revised editions from the U.S.A. These books are, of course, written for American students and farmers. It is not therefore surprising that the principles they expound are illustrated by reference to agricultural conditions in that country. Unfortunately, the principles are sometimes submerged by the volume of descriptive and illustrative matter. No such criticism

can, however, be levelled against Heady and Jensen[1]. In 'Farm Management Economics' they have taken special care to present in a straightforward way the basic economic principles of farm management, keeping the illustrative material subordinate to this general purpose. The result is a readable text-book, though naturally enough some of the chapters will have a less general appeal than others.

Basic principles underlying farm management decisions are set out in Chapter 4. According to the authors, 'all questions of practices, resource combination and substitution, size and combination of crop and livestock enterprises and investment decisions can be answered in terms of these principles. The principles explain the *why* of profitable farm management'.

The authors explain why the law of diminishing returns is so important; they differentiate between fixed and variable resources; examine cost principles; and delve into such questions as diminishing rates of substitution between factors of production and the principle of equi-marginal returns. But they do not lose the reader in a welter of economic jargon, nor do they let the principles become ends in themselves. No previous study of economic principles is necessary to follow the authors' reasoning and the examples they give are apt and to the point. For instance, the concept of fixed and variable costs is discussed in relation to the expenses and returns on an individual farm, and further illustrated by reference to management problems in harvesting grain or fattening pigs.

Farm Planning and Budgeting

Chapter 5 is devoted to the farm plan or budget. This 'is to the farmer what the blueprint or architect's specifications are to the building contractor. It shows what is to be done and how to do it. . . . If we make up budgets for several systems of farming, we predict which one will be most profitable'. The purpose of the budget is to help the farmer to determine the most efficient use of all his resources. It ties together crop and livestock husbandry, capital investment and resource use into a balanced and profitable farming system. The budget may be *complete* and refer to the whole farm, or *partial*, in which case only part of the farm business (such as the poultry enterprise) need be reviewed. The steps in budgeting for a complete farm plan are set out and the reader will soon appreciate the need for having reasonably good information on the relationships between quantities of inputs and the resultant output.

Many of the farming practices referred to in subsequent chapters will be of little direct interest to farmers in this country, but the discriminating reader will not be deterred by the fact that the substitution of machinery for labour, for example, is illustrated by reference to cotton picking, or the economics of farm labour use, by reference to a dairy farm in Vermont. Until such time as a definitive work on the same

subject is compiled in this country, the farm management adviser, student and farmer could do worse than browse on 'Farm Management Economics' as presented by Heady and Jensen.

But many people do not take very happily to reading about economic principles, which, no matter how skilfully served up, seem rather forbidding and remote from farming practice. For them, 'the *why* of profitable farm management' is much less significant than the *how* of profitable management and the down to earth, matter of fact approach to management problems described in 'Farm Planning and Budgeting Services in Farm Management Advisory Work' will doubtless be more to their liking.[2]

The publication consists of the papers presented by a number of experts at a Training Course for a group of farm management specialists from twelve different European countries. The course, which was held in England, was organized by the Ministry of Agriculture and the University of Reading, and sponsored by the O.E.E.C., the main emphasis being on farm management advisory methods developed in this country. Many of the talks were illustrated by individual farm case studies, and farm plans, worksheets and methods are all clearly shown. The twenty separate papers range from the use of yardsticks in analysing the farm business, farm planning and budgeting, advice to farmers as individuals and as members of groups, to the role of the management specialist and the training of advisers.

As this publication is not a text-book, the reader should not expect to find in it a cut and dried line of approach or a well-ordered sequence of thought and repetition of subject matter and diversity of approach is perhaps inevitable. Nevertheless, the papers merit close study by all who give advice on organizing and running a farm.

Productivity in Farming

With the return to freer marketing conditions, emphasis has been given to the need to increase farming efficiency still further, and there is much interest in the question of agricultural productivity. The booklet issued by the British Productivity Council [3] is a useful summary of progress made to date. The contents cover developments since the war, productivity and farm management, work study, mechanization, electricity, buildings, grassland management, and future training.

According to the authors, the first and foremost necessity in farm management is a sound accounting system to assess the extent of profitability of each unit on the farm. Other essentials are labour simplification through job analysis, reduction of inputs (particularly feedingstuffs), ironing out labour peaks, and reorganization of equipment and buildings, etc. Much progress in this direction has been made in farm management advice during the past few years, but the task ahead remains a challenge to all whose aim it is to foster a higher level of efficiency and prosperity in the farming industry. This booklet signposts the ways of achieving further progress.

Analysing Farm Accounts

In a previous issue of this REVIEW* reference was made to the development of methods of analysing a farm business. A further bulletin on similar lines to those already published by Blagburn and Wallace has been written by G. B. Clarke of Leeds University.[4] The author shows how simple farm accounts, kept in the first place for income tax purposes, may be used to highlight weaknesses in the farm organization. The system is essentially that of comparing one farm with standards derived from a group of similar farms. Clarke illustrates his method of analysis by reference to a 200 acre farm in the Vale of York with high yields, but a low profit. A systematic inspection of the records reveals an unduly high level of costs in relation to output and the weaknesses are traced through to their origin. It is a pity that in this case study the author did not include a demonstration of the use of budgets to suggest what remedial action would be most profitable.

Economics of Pig Production

The range in production costs and profitability of pig production is well demonstrated by Burnside and Strong in their analysis of 56 farms producing pigs in the south-west in 1953-4.[6] The costs and purchases are carefully examined, and attention is drawn to the scope and need for reducing the cost of food for a given level of output. Of particular interest from the farm management point of view are the physical data—gradings, food conversion ratios, mortality rates, etc.—which are even more revealing than the bald cost figures when reasons for variations in profitability are being sought.

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3. A Review of Productivity in Farming. *British Productivity Council*, London, June, 1955. 29 pp. Price 1*s*. 6*d*.
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Provincial Note

Farm Mechanization in the West Midlands

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ONE OF THE OUTSTANDING changes in West Midland farming during the past fifteen years or so has been an increased use of machinery. It is true to say, however, that most farmers in the area have been conservative in their general approach to large-scale mechanization. The trend has been a serious effort towards effective mechanization rather than a haphazard introduction of miscellaneous machinery on to the farm. Machines thoughtfully applied and maintained have been found to be the answer to many a manpower problem.

In general, and particularly as regards many of the most efficient large-scale farmers (among whom are some of the best in the country), there certainly has been no rush to introduce machinery for its own sake or just to be in fashion.

The good West Midland farmer has, above all, a keen sense of pride in workmanship—particularly as regards root crops. Machines will have to attain a very high degree of efficiency before he will consider them, unless driven to do so by sheer inability to obtain the necessary labour.

Hand labour is still used very extensively in dealing with potatoes and sugar beet, and many high-class farms with these crops still maintain horses in considerable numbers. Horses combine power with intelligence: the tractor would need to be radio controlled to compete with the horse on equal terms! It is doubtful whether horses will be replaced as they gradually die off, but their retention up to the present time by efficient farmers is an indication that the process of introducing machinery on to farms need not be a hasty one.

On the other hand, some farmers have had to introduce machines as an emergency in order to keep labour on the farm at all. It has also been known for a new machine (though never used) to result in increased production from the casual labour force it was primarily intended to replace! Then there is the occasional instance of the shortsighted grower of a valuable herbage seed crop who fails to make provision for drying. He is to be found transporting his crop to the site of a small and inexpensive electrically-operated platform dryer installed in the first instance to deal with a much less valuable crop.

The cautious attitude of the West Midland farmer towards mechanization is reflected in the unanimous findings of the economists. Increase in production per man since the introduction of large-scale farm mechanization is still small in relation to the capital expended on machinery; compared with 1939 it is estimated to be 30 per cent. But

a large proportion of this output has come from higher yields and better techniques. The extent to which machinery has increased the amount of work done per man is shown in the form of a greater acreage of crops and more livestock tended per man employed. On this basis, labour productivity has only increased by some 15 per cent. If account were taken of the additional man-hours spent in factories and repair shops in the manufacture and upkeep of machinery, this increase in work performance would be even less impressive.

Engineering Interests

The West Midland farmer rarely goes in for dabbling with machinery and the production of time-absorbing 'inventions' which so often prove futile as development proceeds. He is close enough to the industry of the Black Country and factories generally, to be able to keep engineering as such in true perspective, preferring to let the industrialist develop the machines, and to save his own time for efficient farm management. If necessary, however, he will certainly turn his hand to ingenious devices and improvisations.

Occasionally a farmer just has to produce a machine for his own specific purpose, there being nothing suitable on the market. Such an instance is that of a farmer who, growing potatoes extensively on a particularly 'easy' soil, developed a two-row, tractor-mounted elevator-digger to enable some of his exceptionally skilled pickers to deal with 3 tons each per day. There are also many farmers in the area willing to assist the manufacturer with his prototypes. In this way, much that is good in farm machinery has taken practical shape on West Midland farms close to the Black Country.

It is worth recording that the basic tractor-mounted hydraulic loader, which has developed into such a universal multi-purpose implement, was first introduced into this country by a Midland firm after consultation with the N.A.A.S. The first loaders were tried out on a Shropshire farm, near Newport.

Sugar Beet Machinery

The situation of sugar factories at Allscott in Shropshire and Kidderminster in Worcestershire makes the sugar beet crop an attractive one to many farmers in the Province. Successful growing of sugar beet is synonymous with good farming: the crop just has to be done well, with crop rotations strictly observed. The 3,000 growers on 30,000 acres in the West Midlands are naturally interested in mechanical equipment for dealing with the sugar beet, but as for other crops, development is cautious and a great deal of hand work is still done.

'Rubbed' seed is not really popular. There is a suspicion that, compared with natural seed, plant establishment is slowed up, and that ultimate yields can be lower. It is customary to sow natural seed at a high rate of seeding (15 lb. per acre) for the bulk of the crop—certainly for that portion sown in March—and to use 'rubbed' seed for last sowings.

Precision drills are used by about 5 per cent of growers only. Some farmers who have tried them have reverted to a locally made cup-feed drill, the basic design of which has not been changed for more than 50 years. Precision drills are comparatively expensive, they require a perfectly prepared seed bed, such as is not always possible for early sowings, and they need to be operated at very low speeds to give a good performance. At one mile per hour 20 'seeds' per second have to be placed separately at one-inch intervals in the row.

'Down-the-row' thinning machines have been tried to some small extent, with rather encouraging results in some cases. Growers agree that if the labour supply position becomes difficult then the use of precision drills and thinning machines must come.

Good use is made in the area of sugar beet tops and crowns. In 1953, no less than 93 per cent in the Allscott area and 85 per cent in the Kidderminster area were used for feeding stock. Very small quantities are made into silage. Harvesting by hand is ideal as far as feeding-off of the tops and crowns on the field is concerned. The tops are left in rows when cattle and sheep (in particular) clear them up with very little soiling indeed. Most sugar beet harvesters soil and damage the tops to some extent; they certainly do not lay them in neat rows. In consequence, mechanical harvesting has not become very popular in the West Midlands. About 16 per cent of the crop was harvested mechanically in the Allscott area and about 23 per cent in the Kidderminster area in 1953.

If the labour supply becomes inadequate in the area, then resort will have to be made to mechanization; unfortunately as more and more preliminary work (such as 'down-the-row' thinning) is introduced, so the standard of mechanical harvesting will fall. Full mechanization of the sugar beet crop can scarcely result in other than reduced yields.

Mechanization and the Potato Crop

The potato crop in the West Midlands is approximately 17,000 acres of earlies and 55,000 acres of maincrop. Where adequate labour is available, planting is done by hand, particularly the early varieties. There are some 3,000 planters in use, the most common type being the simple machine in which the potatoes are just dropped down chutes into drills opened by the machine. A recent advance in the design of these machines is the introduction of square- or rectangular-sectioned chutes instead of circular ones resulting in more even spacing.

The simple tractor-mounted potato planter may be adapted for fertilizer placement quite easily. Several large-scale growers have done this themselves at a cost of no more than £20. On 100 acres the saving in fertilizer cost has amounted to several hundred pounds, for yields have been well maintained on two-thirds of the normal fertilizer application. It is possible that the introduction of the placement principle on simple planters could result in these machines being much more popular than at present.

Almost without exception, crop cultivations are done mechanically and only under exceptional circumstances is any hand work required. Flexible spring-tined weeders are popular during the early stages of plant growth.

There is some evidence that low-volume spraying just over the top of the haulm may prove economic as regards blight control, particularly if carried out in accordance with forecasts of blight incidence based on meteorological data. The same inexpensive sprayer is used for burning off the haulm prior to harvest. West Midland farmers use a locally produced 'tar oil fraction' (TOF 54) which is very effective and safe to use. It is often collected from the tar distillery by the farmer himself with his own tank, thus reducing the cost considerably. The cost at the farm is approximately 1*s*. 4*d*. per gal., and 15-20 gal. per acre are required.

Although there is some doubt whether 'burning off' assists blight control in the tubers, there is no doubt that the procedure greatly facilitates harvesting. Farmers have found, for example, that after 'burning off', harvesting rates by elevator-digger have increased by as much as 50 per cent. Mechanical destruction of potato haulm created interest when it became known that the scattering of chopped blighted haulm did not lead to an increase in infection of the tubers, provided lifting was delayed for 10 days. Machines for mechanical destruction of haulm are not widely used at present, but the recent development of cheaper machines may soon alter the general picture.

Complete potato harvesters are seldom seen in use in the West Midlands. There are reputedly 86 machines in the area, but it is known that most of these are used to a very limited extent. Consequently at harvest-time very much hand labour is still employed. There have been tentative trials here and there of a system of picking into metal containers holding 5 cwt. or so, which are then handled by tractor loader. With good organization each picker can deal with 2 tons per day in a 10 tons per acre crop, which is considerably above the average by ordinary methods used in the area.

Indoor potato storage has become very popular, particularly since it became known that no elaborate equipment was necessary and that existing buildings could be used with very little modification.

Combine Harvesting and its Effects

It has been generally accepted that combine harvesting of cereals has advantages over other methods—not the least being the capacity of the machine for salvaging damaged crops. In the West Midlands, combines now outnumber threshing boxes by 2:1. A noticeable trend is the increasing demand for tanker combines in place of sacking-off models, despite the disadvantages that the grain cleaner has normally to be dispensed with, and that the tank unloading auger is sometimes unable to deal with beans and herbage seed crops. (In such cases sacking-off

chutes have been built into the bottom of the tank for occasional use.) One-man combining in the field eases harvest to an extent never previously dreamed of. Enterprising growers of second-early potatoes, which come to harvest with the cereals, have found the labour released by one-man combining most useful in getting the potatoes on the market when supplies are short.

The introduction of the combine, however, leads immediately to the problem of drying and storage, and it is now quite evident that no cheap solution of the problem is possible. Drying and storage facilities can cost anything from £8 to £15 per ton of grain stored, depending upon the amount of labour-saving equipment involved and upon whether existing buildings are utilized in the layout.

Some farmers have built good vermin-proof sheds to take their grain either in sacks, in bulk storage on the floor, or in temporary bins; the argument being that such a building may be converted to a piggery, shippon or for other purpose should the need arise. In contrast, it is difficult to envisage any alternative use for many of the elaborate grain installations which are being designed.

Despite the high costs involved in setting up grain installations on the farm, it is becoming clear that such development is inevitable. Good grain installations on farms enable full use to be made of the labour-saving potential of the combine method; they are a means of avoiding marketing gluts, and they remove the need for handling the grain twice, as is the case when central storage silos are used.

Hay- and Silage-Making

Although numbers of farmers have gone in for silage-making on a large scale (particularly in Cheshire), the Province is still predominantly hay-minded. In general, hay is made by established methods with the pick-up baler very popular indeed, but there has been some increase in the tripod method of haymaking. Nationally, the pick-up baler population closely approximates to that of the combine, but in the West Midlands there are 3,500 pick-up balers as compared with 2,500 combines.

Some 650,000 acres of West Midland grassland are mown each year, and there is no doubt that farmers generally are alert to the extra potential possible from the use of improved methods of conservation. Considerable attention is being paid to recent research work which shows that vigorous tedding of heavy swathes soon after mowing hastens drying. Strongly built power-take-off driven tedding machines are rapidly coming on to the market in response to a keen demand. Some of these machines are made locally.

Tripoding, hurdling, racking, and similar systems can only have a limited appeal on account of the labour involved. Attempts at mechanizing the processes are being made with some little success, but in general the methods are only applicable to certain hill areas, or for portions of the hay crop that are potentially high in nutritional value at the outset.

Development in silage-making techniques has proved disappointing in that really satisfactory labour-saving methods for getting the material from pit or clamp to the animals are seldom encountered. It looks as if the silage will have to be sited near to the point of feeding; or indeed it may have to be self-fed. If silage-making is to be a success, water must be kept out of the silo, and therefore properly prepared and roofed installations are essential.

It is still too early to know whether silage-making by pick-up baler is likely to become popular. If it can be shown that advantages result, there would seem to be few difficulties from the mechanical aspect. Up to the present, however, uniformity of quality throughout the mass is often not so good as with silage made by older methods and it has been found locally that little or no saving in labour is effected.

Cultivation and Drying of Herbage Seed

A considerable acreage of herbage seed is grown in the West Midlands. With some crops, particularly cocksfoot, a problem has arisen as to an efficient method of performing inter-row cultivations. Progressive growers have successfully used the rotary cultivator, suitably modified by re-positioning the tine blades, for this purpose.

Seed drying is being done on simple, electrically-operated platform sack-driers. There is no risk of spoilage from overheating. Contract drying by owners of 40-sack-hole-size installations, employing a heat loading of 24 kilowatts, has been done for growers at 12*s.* 6*d.* per hour. About 0.8 per cent moisture is removed in this one-hour period.

As is well known from experience gained in grazing stands of herbage seed crops sown in rows, cattle do not poach the land at all seriously. The idea of sowing leys in rows in order to prolong winter grazing promises to become popular in the West Midlands. Normally cocksfoot (or meadow fescue) alternates with lucerne, in rows one foot apart.

Many ingenious means have been devised for sowing these leys, and it has been found that certain multi-purpose drills can be modified to perform the sowing in one operation quite easily. In the hill country, particularly on fields of irregular shape, the drilling is sometimes done round and round commencing at the outside. In this way mowing of the crop is facilitated because the mower is able to follow the rows without crossing them.

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